REVIEW

APPLICATION OF ADVANCED TECHNOLOGY IN COCOA CULTIVATION : A MALAYSIAN COCOA BOARD JOURNEY

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ABSTRACT – *This paper will focus on the current technology-related studies conducted by Malaysian Cocoa Board in cocoa cultivation aimed at reducing the use of labour and also increasing cocoa yields. It will discuss the factors that limit the cocoa yield, including cocoa maintenance, management and other factors and the methods used to overcome these limitations through innovative research such as smart farming, precision agriculture, management information system, automation, mechanisation and robotics. In cocoa cultivation chain which is from land clearing to cocoa drying, there were a few activities that can be mechanized, automated, and made precise. These included land clearing, planting hole preparation, fertilizer application, pests and diseases management, pruning, pod breaking, and drying. In this paper, we also discussed the major obstacles in the implementation of new technology (smart farming) in cocoa cultivation such as farm size, aging farmers, overhead cost, expertise, internet connectivity and etc. In addition, future works related to advanced technology, for example, the potential use of automated vehicles/machines in cocoa maintenance activities and decision support system were also analysed.*

Keywords: Cocoa, cocoa farm activities, innovative technology, smart farming, technology limitation

INTRODUCTION

Cocoa (*Theobroma cacao* L.) cultivation was introduced to Malaysia since 1778 by the Dutch in Malacca (Wood and Lass, 1985). Since then, a few cocoa trial plots were set up at the research center of the Department of Agriculture in Serdang, Selangor, Cheras, Kuala Lumpur, Kuala Lipis, and Temerloh, Pahang, in 1937 few cocoa trial plots were set up at research centre of Department of Agriculture in Serdang, Selangor, Cheras, Kuala Lumpur, Kuala Lipis and Temerloh Pahang, back in 1937. The first cocoa estate was established in Jerangau, Terengganu in 1950 with a total area of 50 hectares.

The peak of cocoa cultivation in Malaysia was in 1989 with a total area is 414,236 hectares and peak cocoa production was 247,000 metric tonnes in 1990. However, the area and production of cocoa continued to decline after that, making the current area are only 6,123 hectares and the production only 269 metric tonnes in 2023. These decline are due to the outbreak of pest such as the cocoa pod borer and the low price of cocoa beans.

Factors that limit yield can be categorized into three that includes maintenance, management and others. Maintenance factors include pest and disease attacks, low agricultural inputs, poor soil conditions, and poor understanding of agronomy. Management factors include a lack of monitoring, a lack of skilled workers, and deteriorating management standards. While the management factors consists of lack of monitoring, lack of skilled workers and deteriorating in management standards. Other factors are low in cocoa bean prices lead to low productivity and decrease in planting area and changes in weather pattern also contributed to low productivity.

In cocoa cultivation itself, more labor per land area is required compared to other crop commodities. The labor utilization is skewed to certain field operations, mainly harvesting, pruning, fertilizer application, pest and disease management and in-field transportation.

INNOVATIVE AGRICULTURE

Innovation is the introduction of something new whether ideas, methods or devices. Innovative agriculture is the implementation of something new or improved (whether technology or otherwise) in agriculture (goods or services), processes, marketing or organizational methods (IICA, 2014). It may include but are not limited to soil moisture sensor, environmental sensor, GIS-based agriculture, AI (artificial intelligence) in agriculture technology, drones, automation and combining data for crop monitoring.

Advanced technology in cocoa cultivation refers to mechanization and smart farming which includes management information systems, precision farming, and agricultural automation and robotics.

SMART FARMING

Smart farming is a farming management concept using modern technology to increase the quantity and quality of agricultural products including precision equipment, the Internet of Things (IoT), sensors and actuators, geo-positioning systems, Big Data, Unmanned Aerial Vehicles (UAVs, drones), robotics, etc. It represents the application of modern Information and Communication Technologies (ICT) in agriculture, leading to what can be called a Third Green Revolution. Basic philosophy of smart farming is to measure and manage variabilities such as yield, soil, pests, and weeds across fields to enhance the efficiency of managing agricultural practices within the cropping system, ensuring optimal productivity, product quality, economic returns, and minimizing environmental impact and agricultural risk (Larscheid *et al*., 1997).

Smart farming does not target only large and conventional farming exploitations. It is also new levers to boost other common or growing trends in agricultural exploitations such as family farming and organic farming. It provides great benefits in terms of environmental issues includes efficient water use and optimization of agricultural inputs (fertilizer, pesticide, etc.)

There are three things that involved in smart farming which are management information systems, precision agriculture and agricultural automation. Management information system involves people, technology and organization. It is a planned systems for collecting, processing, storing, and disseminating data in the form needed to carry out a farm's operations and functions.

Precision agriculture is where plants (or animals) receive the precise treatment they need, determined with great accuracy. It is the management of spatial and temporal variability to improve economic returns following the use of reduce inputs and eventually reduce the environmental impact. A range of forms of technology are used to this end, including GPS, sensor technology, ICT and robotics to assist in strategic decision-making. With precision agriculture, production of crops will be optimized and resulted in more sustainable crops. The difference between conventional agriculture and precision agriculture is necessary action is carried out for each individual field in conventional, but for precision agriculture, necessary action is determiined per square meter or per plant.

Precision agriculture involved four processes namely observation where it requires sensor to record data from crops or soils, follow by diagnostics which requires specific software complete with decision rules and models. Another process is decision where it determine whether location-specific treatment is necessary or not. And final process is implementation where any treatment will be performed by the correct operation or machines.

Agricultural automation and robotics is the process of applying robotics, automatic control and artificial intelligence techniques at all levels of agricultural production, including farmbots and farmdrones.

APPLICABLE OF SMART FARMING IN COCOA

Under development project of 11th and 12th Malaysian Plan, certain amount of allocation has been put for precision farming. It demonstrates the commitment of Malaysian Cocoa Board (MCB) in adopting smart agricultural technology in cocoa cultivation. Several studies have been carried out to test the efficiency of technologies in cocoa farm management either at nurseries or in the field. Apart from that, some new innovations were also created through various competitions organized at either the internal level of MCB or the national level.

AGRICULTURAL AUTOMATION AND ROBOTICS – NURSERY

In the nursery, among the most time-consuming tasks is filling the polybag with soil. With the DINAMIK filler machine, innovated by a team from Cocoa Research and Development Centre, Madai, Sabah, filling soil into polybags is much easier and faster (Figure 1).

Figure 1 : DINAMIK Filler Machine

In Malaysia, cocoa planting usually uses grafted cocoa seedlings because desired clones can be selected from an early stage of planting compared to planting cocoa hybrid. However, the grafting process is also time consuming and requires skilled workers. With DINAMIK patch budding (Figure 2), grafting activities are more faster and time can be saved.

Figure 2 : DINAMIK patch budding

An automated fertigation system in cocoa seedlings production is crucial because it requires a consistent water supply to maintain healthy growth during the nursery stage. With automated fertigation system, water supply for cocoa seedlings can be controlled and monitored using tablet or mobile phones. If there is something wrong with the irrigation system, such as a clogged pipe and water not reaching the seedlings, the system in the mobile phone will warn by showing a low soil moisture reading that is not suitable for plants. An automated fertigation system can reduce the use of manpower to water the plants every day and enhance more efficient nursery management.

Figure 3 : Automated fertigation system in cocoa nursery

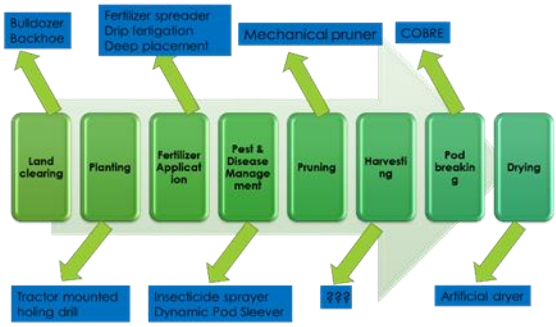

Figure 4 : Mechanization and automation in upstream cocoa production chain

AGRICULTURAL AUTOMATION AND ROBOTICS - FROM LAND CLEARING TO DRYING

In the cocoa production chain, starting from land clearing to dry cocoa bean storage, there are few activities that have been mechanized or automized (Figure 4) (Rozita, 2018a, Rozita *et al.*, 2018b). In land clearing, heavy machineries such as excavator, bulldozer, backhoe and other suitable equipments are often been used (Figure 5).

Figure 5: The use of heavy machineries during land clearing

For planting hole preparation in larger areas, an excavator with a suitable bucket and a hole digger is usually used (Figure 6). However, a hole digger is not recommended for harder soil textures because it can lead to soil compaction and restrict root growth, eventually making plant growth stunted.

Figure 6a : Use of machineries for planting hole preparation (excavator)

Figure 6b : Use of machineries (planting holes maker) for planting hole preparation

There are few major field maintenance activities in cocoa, including fertilizer application, insecticide spraying, and pruning. With the use of tractor-mounted fertilizer spreader (Figure 7) and sprayer, much time can be saved up. Fertilizer application also can be carried out by drip fertigation (Figure 8) and deep placement (Figure 9) to save time of application.

Figure 7 : Fertilizer application using fertilizer spreader

Figure 8 : Drip fertigation study in Cocoa Research and Development Centre in Bagan Datuk

Figure 9 : Deep placement study for fertilizer application in cocoa plantation

For pest and disease management, power sprayer (Figure 10) can be used to spray pesticide in bigger area. However, in smaller area, especially for smallholders, DINAMIK Pod Sleever (Figure 11) is used to sleeve pod to control cocoa pod borer by mechanical barrier.

Figure 10 : Power sprayer to control pest in cocoa plantation

Figure 11 : DINAMIK Pod Sleever for pod sleeving

Other field activities is pruning. It is also an important field maintenance that has to be carried out in order to get high yield. For pruning, mechanical pruner can be used, however, it is still under research. There are two types of pruner, one is use to remove water shoot (Figure 12) and another one is to prune excessive branches or unwanted branches (Figure 13).

Figure 12 : Pruner to remove water shoot

Figure 13 : Pruner to remove branches

In the cocoa production chain, to date, there is no specific equipment to facilitate cocoa harvesting. It needs to be cut one by one and it is time consuming. Although harvesting seems to be like a simple activities and can be done by anybody, but through our experiences, when it is carried out by non-skilled workers, they can only harvest less than 10 kilogrammes cocoa wet bean/person and it is not worth for their wages/day. Therefore, it is crucial to develop any automation or mechanization in harvesting.

For pod breaking and separation of cocoa bean and cocoa pod, there is a machine called COBRE® that has been developed by MCB to do this job (Figure 14). With this machine, the use of labour can be reduced to one worker compared in normal situation, it needs three persons.

Figure 14 : COBRE®, a machine for cocoa pod breaking and bean separation

For cocoa drying process, the best method is through sun dry. However, usually in Malaysia, the peak season for cocoa harvesting coincide with raining season which is in November to January. Therefore, the use or artificial dryer (Figure 15) is very useful to avoid cocoa bean from mouldy.

Figure 15 : Artificial dryer to dry wet cocoa bean

DEVELOPMENT OF COCOA PLANTING SYSTEM FOR MECHANIZATION AND AUTOMATION

In order to adopt the mechanization and automation in cocoa cultivation, planting system or planting pattern of cocoa need to be revised. Previous study in 2007 (Rozita, 2014, Rozita *et al*., 2017) showed that 4 rows of cocoa with 5m mechanization path (Figure 16) is suitable to facilitate tractor mounted fertilizer spreader and sprayer to pass through the mechanization path. This system can reduce the time for fertilizer application and insecticide spraying by up to 36% compared to the normal system.

Figure 16 : New planting system for cocoa, 3m x 3m planting distance with 5m mechanization path

Current study on the planting system is on the trellis planting system (Figure 17) with 1m x 1m planting distance and 4m mechanization path. This study is still ongoing. This study aims to reduce labour intensity in cocoa cultivation with mechanized operations in fertilizer application, pest and disease control and pruning activity.

Figure 17 : Development of new planting system called trellis, 1m x 1m planting distance with 4m mechanization path

PRECISION AGRICULTURE IN COCOA

Study 1

Quantification of spatial and temporal of variability on soil, CPB infestation rate and fresh cocoa bean at two different planting systems of cocoa-gliricidia and cocoa-coconut (Tee *et al.*, 2023).

Results showed that precision cocoa farm management helped to increase crop yield by 58.8 and 51.1% at cocoa-gliricidia and cocoa-coconut, respectively.

Study 2

Fluorescence sensor and spectroradiometer (Figure 18) are used to provide information on the status of secondary metabolites of cocoa during pod development and the wavelength indicator when plants experience drought and water stress. Leaf and canopy optical properties which are influenced by the concentration of chlorophyll pigments responsible for photosynthesis, are found to absorb radiation especially in the regions of the electromagnetic spectrum centered around the blue (450 nm) and the red (650 nm) reflectance.

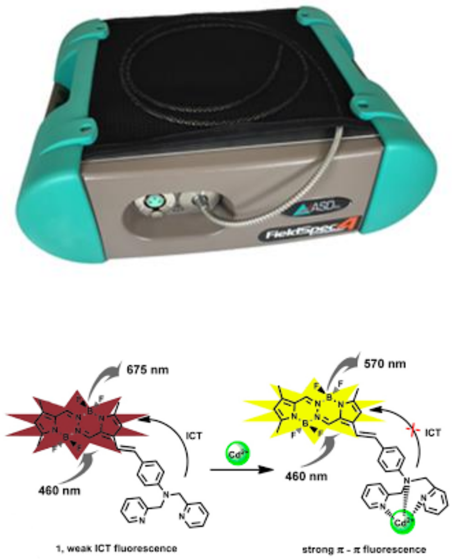

Figure 18 : The use of spectroradiometer to provide the secondary metabiolites status of the plants

MAJOR OBSTACLES TO COCOA SMART FARMING

Although there is a big potential in implementing cocoa smart farming in Malaysia, there are few factors that have to take into considerations. Farm size is one of the factors that limit cocoa smart farming. Most of farm size is less than 1 ha especially in West Malaysia. Most of the activities that involve mechanization such as fertilizer application using tractor mounted spreader or insecticide spraying are not suitable for small farms. Apart from that, the aging farmers (age above 60 years old) are also less capable to carry out activities that involve the use of modern technology such as drones, artificial intelligent (a.i) and others since they have never been exposed to this kind of technology. Gaps in knowledge and skills, especially among cocoa smallholders, also contribute in developing smart farming.

High initial capital cost to set up farm that has smart farming technology may also be a major obstacles as we know that most of the technologies are very costly. There are also a rapid changes in technology, making it not worthwhile to invest a lot of money for only short-term use before the technology changes again. Since smart farming involves big data in a system which might be developed by third party, data security and privacy will be major issues. Big data management in smart farming is not easy. It includes a lot of data on weather pattern, soil fertility, yield data, etc. This data needs to be properly arranged so that it becomes meaningful data that can be used in smart farming management. It requires highly skilled personnel to manage the data.

In the early stages of smart farming development, a lack of quantification of the costs, benefits, and risks of the new practices is expected, along with resistance to change.

CONCLUDING REMARKS

Smart farming is goal-oriented and hinges on the advent of information technology, affordability of key technologies such as GPS, sensors and yield monitors, agronomic knowledge of the crop and management strategy and system.

Its applicability for cocoa plantations also depends on the success of mechanization of most field operations e.g. fertilization, pruning, harvesting and yield collection, and the attitude and readiness of the management/farmers to change. Mechanisation of most operations is an absolute necessity for smart farming to materialise in cocoa plantations.

The machines will allow data loggers, yield monitors, GPS, sensors etc to be fitted for data collection. However, the accuracy and precision of the data and generated yield maps need further investigation.

Yield can be optimized by optimizing inputs through smart farming including management zone and fertilization. Creating of management zone based on crop age, agronomic, soil information – most effective means to optimize inputs.

Agronomic research should target on understanding yield variation at a finer scale than currently done. The results are important towards the success of attribute mapping and interpretation of yield maps, and development of decision support system (DSS).

Methods to combine spatial and temporal data and a protocol to interpret yield maps are under developing for cocoa. Decision support system (DSS) translates data into knowledge for differential actions in the fields generally by combining database, crop models, expert system and artificial intelligence. Work should commence on the next generation of DSS which will be web-based and accessible through handheld equipment including mobile phones.

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